2.—The Warburton Range nickel-rich ataxite

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Abstract

A new find of a large single mass of meteoritic iron in the Warburton Range area of Western Australia has proved, on sectioning, etching, and mineragraphic study to be a nickel-rich ataxite containing an unusually high percentage of nickel and cobalt in the metal phase. Chemical analysis shows that it contains 19.08 per cent nickel and cobalt. The meteorite is a single mass showing surface ablation markings and details of external features are briefly given.

Introduction

The Warburton Range iron meteorite, a new find in Western Australia, was briefly mentioned in a Catalogue of Western Australian meteorite collections (McCall & de Laeter 1965, p. 18) and in a report on the progress of meteoritics in Western Australia (McCall 1965). In this paper more complete details of this new and rare iron meteorite, now confirmed as a nickel-rich ataxite, are given.

Details of the find

In December 1963 or January 1964 two prospectors working near the Warburton Mission, in the eastern part of Western Australia, recovered a single mass of meteoritic iron weighing 125½ lbs. This mass was brought in to the Native Welfare Department at Kalgoorlie by the finders, Messrs. H. Gill and G. Sims and, after identification of the mass as meteoritic iron by members of the staff of the School of Mines, Kalgoorlie, it was lodged in the collection of the Western Australian Museum as Specimen No. 12295.

This discovery was made 12 miles south of the Warburton Mission on sand amid broken outcrops of sandstone, and reports indicate that the meteorite was lying on the surface, not buried. The location was initially given as 25 miles south-west of the Warburton Mission, but a more accurate position has been given by Mr. J. H. Lord (fig. 1) and the approximate co-ordinates are: East 126° 40′; South 26° 17′.

External features

The single mass is of crudely conical form (fig. 2, A, B, C) and shows a distinct flattened sole (fig. 2, D) which appears rough and weathered, suggesting that this is the surface upon which the mass rested from the time of fall to the time of discovery. The other faces are, in contrast, less eroded and show a shiny film of oxide coating. This film is thin, however, as is shown in the cut section illustrated in figure 3, and the interior of the meteorite is uniformly fresh. Regmaglypt patterns are present on the three side faces of the cone, and weakly so on the basal face. Clearly it is a single meteorite which was not fragmented at any time during the later stages of atmospheric flight or on impact. However, no distinct orientation of surface markings indicating attitude in atmospheric flight can be detected, though such a pattern is typical of single, unfragmented meteorites.

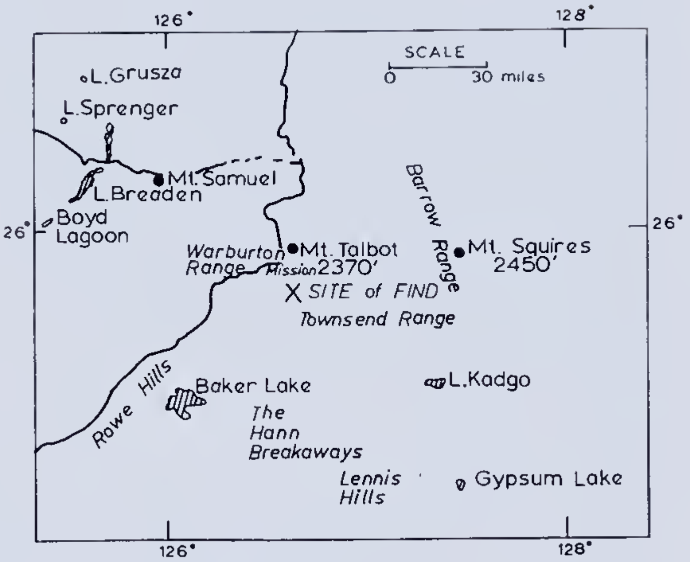

Figure 1.—Sketch map showing the location of the Warburton Range meteorite. Solid lines are tracks.

Specific gravity

The freshness of the mass and small size and scarcity of troilite inclusions means that the specific gravity values obtained will be consistent. Measurement on a cut section gave a value of 8.05.

Internal structure

When first examined this meteorite was believed to be an octahedrite, for a pattern of intersecting linear markings was noticed on the shiny outer surface, suggesting a weathered-out Widmanstatten pattern, such as is evident on Tieraco Creek (McCall & de Laeter 1965, p. 50). It was secured for the Museum more on account of its external features and size rather than because of any suspected rare quality. However, after cutting and etching with 8 per cent. nital reagent no distinct pattern was developed, even after etching for several minutes. On careful examination it was found that there is evident. (a) very fine dark mottling and minute white specks within the dark mottles, and (b) very sparse rods of a grey mineral which appears to be troilite and ranges up to 3 mm long. These features are seen in the cut section illustrated in figure 3. The first etch tests produced somewhat blurred results but, on the advice of Mr. E. P. Henderson, of the Smithsonian Institution, Washington, very light etching for 10 seconds with the same reagent was found to produce excellent results, as is seen in the two polished sections illustrated in figures 4 and 5.

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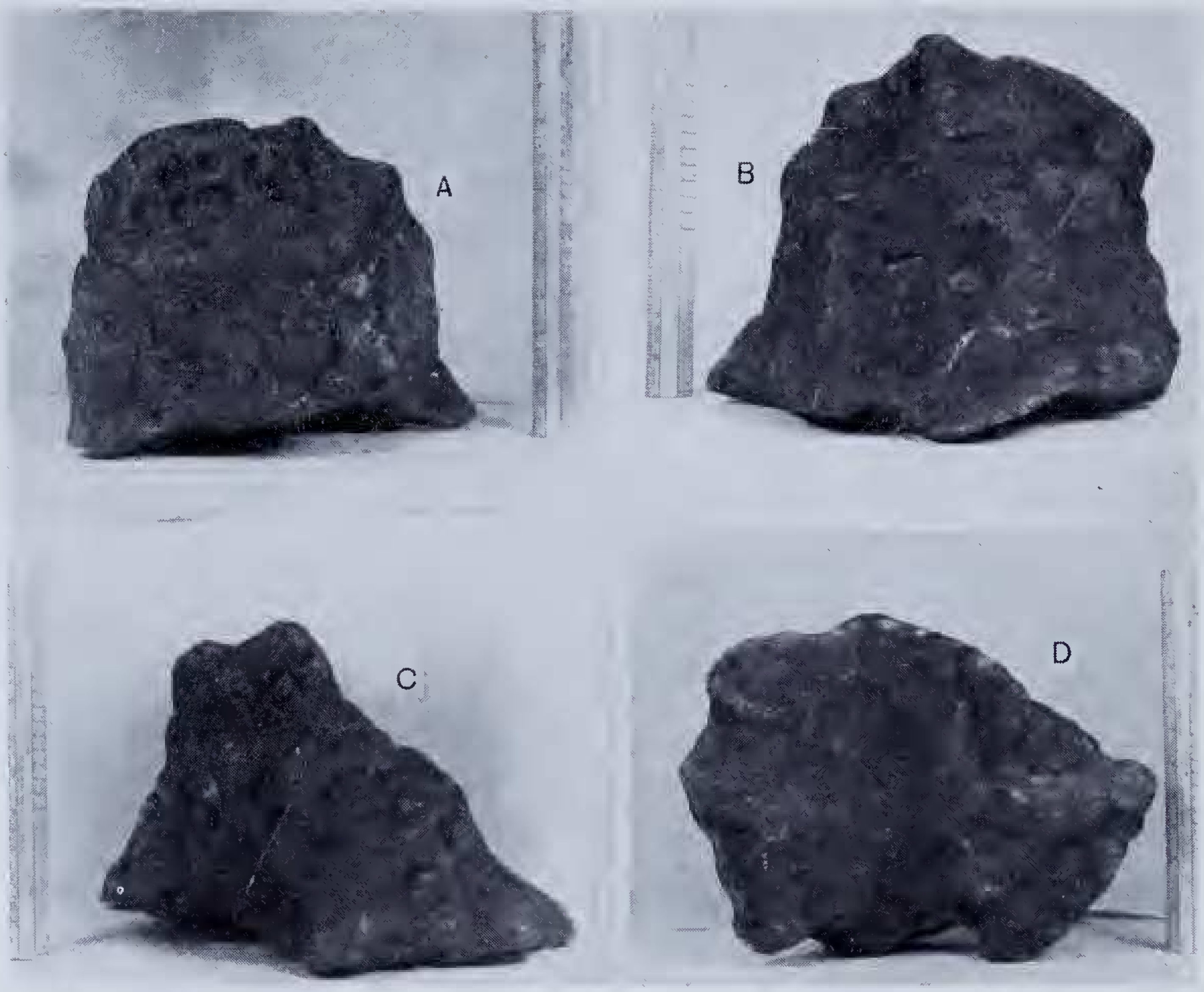

Figure 2.—Western Australian Museum No. 12295. External features of the single mass of the Warburton Range ataxite, showing (A, B, C) regmaglypts on three sides of the roughly triangular tapering cone. The flat sole on which the meteorite is resting in these views is the roughened surface on which the regmaglypts have been partly obscured by weathering (D). The scale in the photographs is 12 inches long.

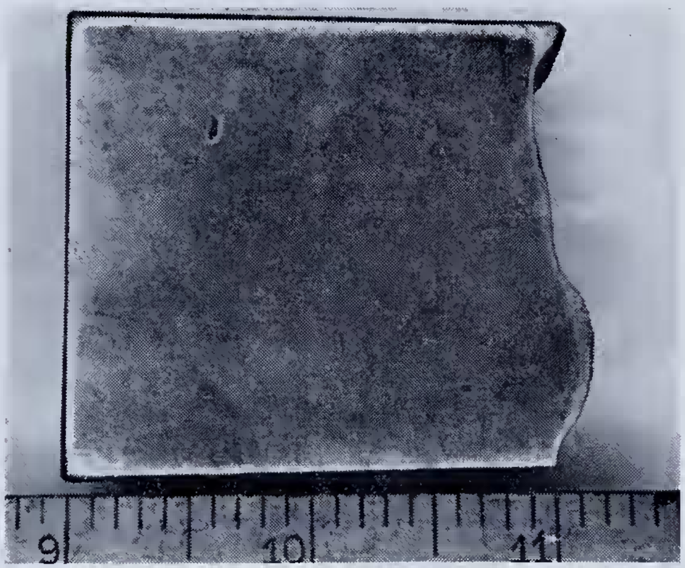

Figure 3.—Cut and polished section of the Warburton Range ataxite showing faint, fine, dark mottled areas and light, inset specks which are larger needles of kamacite. One troilite rod shows, upper left. Scale bar in inches.

Mineragraphy

The etch pattern was studied under reflected light with vertical illumination. The dark mottling evident in figure 3 is seen to be due to areas which are relatively free from minute kamacite needles, and composed entirely of plessite, too fine to be resolved into its components under the optical microscope, and single or clustered kamacite laths larger than those of the fine base network (fig. 4). The plessite mottlings are up to two millimetres in diameter and the largest kamacite laths not more than half a millimetre long. The texture might perhaps be described as microporphyritic or microglomeroporphyritic, but the absence of matrix needles in the vicinity of the "phenocrysts" makes this analogy with textures seen in thin sections of igneous rocks unsatisfactory. The phases present are kamacite (alpha nickel-iron) and taenite (gamma nickel-iron), together with plessite, a "paracutectoid" composed of very fine intergrowth of these two minerals. The taenite swathes the reflectant kamacite (figs. 4 and 5) in even more reflectant rims, completely or partially surrounding it. The plessite appears dull grey, finely granular and non-reflectant under high magnification, but although this fine granularity indicates its composite nature it cannot be resolved into distinct mineral grains by the optical microscope. The boundaries between taenite and plessite are indistinct, but, in contrast, those between kamacite and taenite are sharp.

A modal analysis (573 points) gave the following result:

	Volume per cent.
Kamacite	17.0
Taenite	10.3
Plessite	72.7

No troilite was recorded since this is present as very sparse rod-like inclusions (fig. 3). Its identity was confirmed by means of a sulphur print, which also revealed a few minute specks of troilite disseminated in the kamacite-taenite-plessite base. It is possible that a little schreibersite is included with the kamacite.

Figure 4.—Photomicrograph of a mottled patch (see fig. 3). An area of plessite includes a single large taenite-swathed kamacite needle, possibly aggregated with one other smaller granule. The more reflectant nature of the swathing taenite is apparent. The groundmass of smaller, but similarly taenite-swathed, kamacite needles is seen on the left-hand side of the photograph. A black speck (lower, centre) could be a silicate inclusion. Scale: x60.

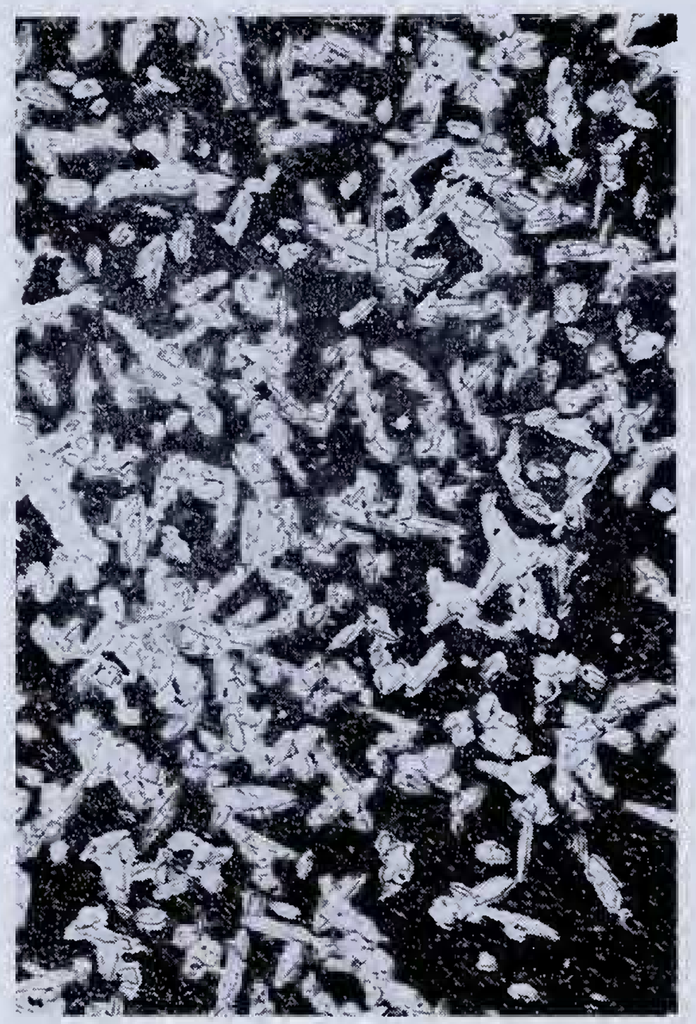

Figure 5.—Photomicrograph of a fine groundmass of kamacite needles, partly or wholly taenite-swathed, and set in less reflectant plessite. The needles of kamacite show an octahedral pattern in their arrangement but there is no suggestion of lamellar structure. The plessite appears finely granular but cannot be resolved into its components. Scale: x60.

Chemical composition

Nickel was first determined by J. R. de Laeter, who obtained the surprisingly low value of 10.2 per cent. (McCall 1965). The material was subsequently analysed by one of us (H.B.W.), when the expected higher nickel content compatible with the ataxitic etch pattern was obtained. The later results are:—

	Weight per cent.	
Fe	80.22	
Ni	18.21	19.08
Co	0.87	
Total	99.30	

The remaining 0.70 per cent. could be partly sulphur in the troilite, and minor constituents in trace amounts such as are invariably present in meteoritic iron.

Discussion

The bands of kamacite in iron meteorites become progressively narrower as the nickel-cobalt content increases from the values typical of octahedrites (6 per cent. upwards) towards the boundary between octahedrites and nickel-rich ataxites (about 14 per cent.). The Widmanstatten patterns composed of intersecting lamellae are replaced by patterns of discrete kamacite grains, fringed by taenite, within a continuous plessite base. Almost all ataxites possess a microscopically detectable structure of this sort, even though their name is somewhat misleading, and the criterion of a nickel-rich ataxite is the absence of intersecting lamellae, not a complete lack of etch pattern (Perry 1944, p. 65). The transitional forms of 12-14 per cent. nickel content are difficult to refer to either class of iron meteorite; they may possess the typical ataxitic pattern of discrete kamacite needles, but show, here and there, traces of intersecting lamellae. This transition is also complicated by the fact that there is no exact correlation evident between structural pattern and chemistry (although some of the apparent anomalies may be due to inaccurate analytical techniques). The fact that needles show an octahedral orientation is no indication at all that the meteorite is an octahedrite; all nickel-rich ataxites show this octahedral structure if they show any systematic arrangement of kamacite needles at all (*ibid.*). There is no problem in classifying the Warburton Range iron since it shows no intersecting lamellae at all, and has a nickel-cobalt content well in excess of the transitional value. It is, in fact, the second highest nickel-cobalt content of any Australian meteorite, being only surpassed in this respect by Wedderburn, Victoria (Edwards 1951); for comparison, the compositions of the more nickel-rich iron meteorites from Australia are set out in Table I.

Only some 38 nickel-rich ataxites are now known (Mason 1962, p. 42; Baker *et al.* 1964) and all are finds. No fall of an iron of this type has ever been observed,* but falls of irons are in themselves extremely rare, and the overwhelming majority of irons are octahedrites. Although this type of meteorite is rare, the largest single meteorite mass known is of this type (Hoba, South West Africa; about 60 tons), so it is certain that ataxitic iron occurs in enormous masses and is not just a minor, localised development in the more usual types of meteoritic iron.

The nearest relation amongst Western Australian meteorites is Mount Magnet, which has a transitional structure: areas of intersecting lamellae and areas of discrete needles in plessite like this meteorite.

TABLE 1

Compositions of the more nickel-rich iron meteorites from Australia

	1.	2.		3.	4.	5.
		(a)	(b)			
Fe	86·24	85·66	....	82·29	80·22	74·35
Ni	13·43	13·66	14·72	16·90	18·21	23·95
Co	0·16	0·77	0·54	1·09	0·87	0·50

Explanation :

1. Corowa, New South Wales (Baker *et al.* 1964).
2. Mount Magnet, Western Australia (Simpson 1927 ; Lovering *et al.* 1957)
3. Tawallah Valley, N.S.W. (Hodge-Smith & Edwards 1941).
4. Warburton Range, Western Australia.
5. Wedderburn, Victoria (Edwards 1951).

Analysts : 1—T. H. Donnelly ; 2—(a) E. S. Simpson, (b) J. F. Lovering ; 3—Chemical Branch, Department of Mines, New South Wales ; 4—H. B. Wiik ; 5—G. C. Carlos.

All values are weight per cent.

Structures of the type seen in this new ataxite from Warburton Range are supposed to reflect more rapid phase change in past transformations than has occurred in octahedrites (Uhlig 1954, p. 290). Baker *et al.* (1964, p. 1386) conclude that in view of the absence of definite information concerning pressure conditions operating in the parent body (increased pressure would allow gamma-alpha phase transformations at a lower temperature) little can be done in the way of accurate estimation of the likely range of transformation temperatures applicable to this alloy type, and the rate of growth of the kamacite from taenite is equally difficult to assess.

Further investigations

This material is so fresh that it presents an ideal subject for electron probe and spectrochemical trace element investigations. There is no facility for the former in this State and, while the latter could be attempted, it has been considered better to present this introductory account, leaving the detailed physical and geochemical aspects to be treated separately later.

Acknowledgments

We are indebted to the finders, and to Messrs. J. Harman and W. H. Cleverly of Kalgoorlie for bringing this new meteorite to the notice of the Museum authorities. Assistance was given by Dr. B. H. Mason, of the American Museum of Natural History, New York and Mr. E. P. Henderson of the Smithsonian Institution, Washington. The mass was initially cut by the Commonwealth Steel Corporation, Perth. Mr. J. H. Lord, Director of the Geological Survey of Western Australia, visited the site and supplied an accurate location. The help of Mr. J. R. de Laeter in various ways, and Mr. K. C. Hughes and Mr. W. Smeed in preparing the photographic illustrations and polished sections respectively is also acknowledged.

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* Note added in proof: A nickel-rich ataxite fell at Muzzaffarpur, India, on 11 April 1964 (Krinov, E. L., 1964, Meteoritical Bulletin No. 32, pp. 1-2).